Effects of Fluid Mud on Bottom Boundary Layer Dynamics and Sediment Fluxes at Mudflats

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LONG TERM GOAL

The scientific goal of this project is to understand the effects of spatial and temporal variability of estuarine circulation and sediment fluxes on the morphodynamics of intertidal mudflats. The methodological goal is to develop reliable predictive tools and sensing techniques that document the hydrodynamics, sediment/substance transport and morphodynamics at mudflats.

Specific Objectives of this study:
In FY07, we have participated and assisted in the planning of the tidal mud flats field experiment. We have actively attended the research project meetings in order to share our research ideas and coordinate our resources with the overall DRI team. Our specific objectives of this project are:

1) to understand the effects of mud suspension on flow energy dissipation at the bottom boundary layer, on the bottom stress, and consequently on the mud transport itself;

2) to develop appropriate parameterizations of the bottom drag coefficient for estuarine/mudflat hydrodynamic models; and

3) to understand the mechanisms for the direction and magnitude of sediment transport at mudflats in response to hydrodynamic forcing at intratidal (ebb-flood) timescales and at fortnightly (spring-neap) timescales.

APPROACH

Our existing understanding of the bottom boundary layer energy dissipation in muddy environments is not sufficient. Specifically, when concentrated fluid-mud is present in the bottom boundary layer, it

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significantly modifies the mean flow and turbulent flow fields and the conventional logarithmic "law-of-the-wall" becomes tenuous. Some studies address this problem by using the "drag reduction" paradigm (Wang 2002). This paradigm suggests that the presence of near-bottom suspended sediments causes an increase in water column stratification (e.g., Glenn and Grant 1987; Green and McCave 1995) that reduces the turbulent energy dissipation and the bottom drag. Such a reduction in bottom drag results in mean flow increase. However, we question here that the "drag reduction" paradigm may be incomplete and needs to be revisited. Because of concentrated fluid-mud, surface waves attenuate over muddy seabeds (e.g., Maa and Mehta 1990; Sheremet and Stone 2003). Therefore, it is also possible that the presence of mud causes enhanced energy dissipation associated with the mean flow and therefore, flow reduction. Because predicted estuarine circulation and sediment transport are sensitive to the bottom drag (e.g., Valle-Levinson et al. 2003), our research question is also relevant to large-scale coastal/estuarine numerical modeling efforts.

Understanding the mechanisms driving the direction and magnitude of sediment fluxes under different tidal conditions is critical to the development of overall predictive skill of mudflat morphodynamics. At a sandy beach, it is well-established that onshore sediment transport occurs during calm weather while under stormy conditions, offshore transport and beach erosion prevail. The dominant physical mechanisms driving sand onshore/offshore are also more or less understood. Interestingly, according to limited field observations at mudflats (e.g., Bassoullet et al. 2003), landward sediment fluxes develop from tidal resuspension due to flood flow during calm conditions, while seaward fluxes may develop from local wind-wave resuspension in conjunction with ebb flow. However, thorough measurements are needed to understand the physical mechanisms responsible for these transports and to propose reliable modeling approaches.

At mudflats, it is clear that slight tidal asymmetries (at both flood-ebb and spring-neap) can cause net landward or seaward sediment fluxes. The tidal current intensity over a mudflat is strongly influenced by the bottom drag. As described above, 1) the bottom drag is also influenced by the presence of mud. Accordingly, some questions further arise. How does the interplay between tidal current, bottom drag and mud determine the resulting sediment fluxes? Specifically, is the information on tidal currents sufficient to explain the observed sediment fluxes? And is it necessary to consider the nonlinear response of mud to the hydrodynamic forcing? We suspect that other mechanisms at mudflats can further enhance (or cause) landward/seaward asymmetries and net sediment fluxes. For example, in a macro-tidal environment, can episodic storm-wave events cause local resuspension and offshore transport? Can the spatial heterogeneity of the mudflat cause major transport in a preferred direction?

The PIs in this proposal are interested in using various measurement techniques (Sheremet and Stone 2003; Valle-Levinson et al. 2003) and detailed modeling (Mehta 1989; Hsu et al. 2007) approaches to address the proposed science questions.

WORK COMPLETED

As mentioned, in FY07 we actively participated in the research planning meetings in Honolulu, HI and Incheon, Korea and exchanged our ideas with other participants. We would like to collaborate with other field experimentalists who share similar scientific interests to conduct more comprehensive measurements on various aspects of estuarine sediment transport processes in the boundary layer. Phase 1 will allow us to effectively fine-tune our modeling and experimental efforts. Finally, we plan to disseminate our effort to estuarine/coastal modelers so that a detailed understanding of sediment-

laden boundary layer dynamics and sediment fluxes can be used to improve our predictive skills related to mudflat morphodynamics.

In October 21-22, the PIs will also participate in the new site visit in Skagit River delta in Puget Sound, and Willapa Bay in the southwestern part of the Washington state. With more comprehensive understanding on the new sites, it is likely that the science questions that are previously formulated can be appropriately studied with only minor modifications.

As a result of the planning visits to Hawaii, Incheon and upcoming field site visit to Skagit River delta and Willapa Bay, we are intending to address specific questions related to the overall project objective of determining the relative contributions of tides, river and winds on the overall circulation and sediment transport in the study region. To that end, we would like to establish the spatial variability of flows, both along and across the estuary, as determinants of the sediment transport in the area. Particular attention will be placed in the spatial structure of tidal, subtidal and overtidal flows throughout the system with data obtained in the field. The data will be collected with fixed and towed instrumentation during various tidal, wind and river discharge conditions. These data will also help to feed numerical simulations intended by us and other PIs. It is also expected that significant amount of field data on cohesive sediment suspension, evolution of mud bed properties and erodibility will be measured, which provides invaluable opportunity to validate numerical models. Hence, small-scale bottom fluid mud models will be further extended to directly resolve the consolidation and fluidization processes of the mud bed along with variable floc structures.

In summary, the PIs at University of Florida are currently preparing several coherent proposals for the pilot study at Skagit River delta, and Willapa Bay. These proposals will cover both field experimental campaign and detailed numerical modeling.

RESULTS

New start in FY07.

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PUBLICATIONS

New start in FY07.